MINI-SYMPOSIUM: SHOULDER RECONSTRUCTION

(iv) Shoulder arthrodesis

David Limb*

Chapel Allerton Hospital, Leeds LS7 4SA, UK

KEYWORDS

Arthrodesis; Arthroplasty; Infection

Summary

Shoulder arthrodesis is rarely performed, but is a valuable reconstructive option for difficult shoulder problems. The success of shoulder arthroplasty has significantly diminished the frequency with which this operation is carried out. However, the durable results of arthrodesis have stood the test of time and it remains the operation of choice for highly selected patients with various forms of paralytic and destructive pathology about the shoulder, particularly problems that are not suitable for shoulder replacement.

Indications

The main indications for shoulder arthrodesis are listed in Table 1. If the technical skill has been mastered then arthrodesis can be considered in the range of 'one off' difficult reconstructive cases that present to the specialist shoulder surgeon with tumour, trauma or infection, or indeed a combination of these aetiological factors.

It is contraindicated if there is no scapular control, if there is a progressive underlying neurological problem, in the face of active sepsis and if the patient would not be able to cope with the rehabilitation demands afterwards. It should also be considered as contraindicated if the underlying pathology can be treated in any other way that preserves shoulder function, particularly shoulder arthroplasty, except in exceptional circumstances.

Infection was the major indication for shoulder arthrodesis in the era before antibiotics. Extra-articular arthrodesis was therefore developed, as exemplified by the arthrodesis between the greater tuberosity and acromion described by Watson Jones. After bringing the decorticated surfaces into contact a plaster spica was applied and had to be worn continuously for 4 months. Brittan described a technique using a tibial cortical strut graft between the medial shaft of the humerus and the lateral column of the scapula—a truly extra-articular arthrodesis, but with the potential for significant complications, including donor site morbidity. An inevitable consequence of the techniques that were developed to bring the articular surfaces together was that the tendon of the long head of the biceps had to be sacrificed. Moseley described biceps tenodesis in its humeral groove specifically to facilitate bone-to-bone contact in the shoulder whilst minimising the cosmetic effect of biceps division and the loss of supination power that can accompany this.

Modern techniques

As intra-articular arthrodesis between the humeral head, glenoid and acromion became more common, with removal of the cortical layer from the three surfaces to be fused, so
methods of compression fixation were explored to bring the denuded bone surfaces into contact. Perhaps not surprisingly, Charnley has described compression arthrodesis at the shoulder, an extension of his successful development of the techniques using Steinman pin external fixation that he popularised in other joints, particularly the knee and ankle. In 1970 the ASIF described compression plate fixation and this has been the standard method since. The main modification to this has been to gravitate towards using a single plate rather than the double plate technique originally described (Figure 1).

The technique of plate fixation follows straightforward AO principles—after denuding the surfaces of the humeral head, glenoid and acromion, the humeral head is compressed into the two scapular surfaces using the lag screw principle. This fixation is then protected by using a neutralisation plate across the joint. The lag screw(s) can, with proper planning, be inserted through the precontoured plate if required. It is important to note that the lag screws require long unthreaded shafts to glide through the humeral head and short threaded sections at the tip to gain purchase in the relatively limited bone available in the glenoid. The best scapular fixation is in the glenoid and although a significant length of plate can be contoured to run along the scapular spine, the bone of the spine is very thin and often only short screws will be accepted. It is still therefore common to brace the arm afterwards, though this can be removed to facilitate the rehabilitation programme that is required.

**Surgical technique**

**Planning**

Ensure that there is sufficient bone for compression arthrodesis. This is particularly important if there have been shoulder arthroplasty implants in situ or in cases of tumour resection. The arm can be shortened by a few centimetres without any diminution of function, but consideration can be given to autologous bone grafting or even allograft if there is significant bone loss. In very difficult cases free tissue transfer may be required, such as free fibular transfer, and cooperation should be sought from a plastic surgeon.

If an adjustable brace is to be used after surgery then this can be fitted before surgery. The patient can even wear it for a few days to accommodate to the level of inconvenience that they are likely to face after surgery. It is much easier to fit and adjust the brace when the patient is mobile and can stand upright than when they are recovering consciousness on an operating table.

**Patient positioning**

Access is required to the spine of the scapula, acromion, deltoid and anterolateral humerus. Furthermore it should be possible to accurately assess the position of the arm in relation to the body during surgery, as it will be extremely difficult to change the position after arthrodesis. The beach chair position fulfils these requirements, preferably on a table designed for shoulder arthroscopy, which allows good access to the back of the shoulder. If free tissue transfer is required then the patient position may have to be modified, or provision made for a change of position during the procedure. Similarly access for structural grafts should be considered if substantial bone is to be excised, such as in cases of failed arthroplasty or tumour.

**Approach**

The incision extends along the lateral 10 cm or so of the scapular spine to the tip of the acromion, turning smoothly to run over the acromion onto the anterolateral aspect of the humerus, splitting the deltoid (Figure 2). Often there is no deltoid function when arthrodesis is being carried out, so there is no need to worry about axillary nerve injury. If arthrodesis is being carried out in the presence of an innervated deltoid then it is desirable to keep the axillary nerve intact to reduce the speed and extent of deltoid

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Indications for shoulder arthrodesis.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flail shoulder with functional hand/arm (e.g. brachial plexus injury)</td>
<td></td>
</tr>
<tr>
<td>Some cases of axillary nerve palsy</td>
<td></td>
</tr>
<tr>
<td>End stage septic arthritis</td>
<td></td>
</tr>
<tr>
<td>Failed shoulder arthroplasty</td>
<td></td>
</tr>
<tr>
<td>Some cases of shoulder instability</td>
<td></td>
</tr>
<tr>
<td>After tumour resection</td>
<td></td>
</tr>
<tr>
<td>Occasionally osteo- or rheumatoid arthritis, cuff tears and malunion</td>
<td></td>
</tr>
</tbody>
</table>
shoulder. In this position it can be contact with the humeral head whilst the head itself makes acromion, with its attached deltoid, to flap down into to osteotomise the spine of the scapula to allow the undersurface of the acromion. It is acceptable if this occurs to have excellent bone stock but the contact area with the glenoid is diminished by pushing the humeral head upwards.

Acetabular reamers of a similar size to the humeral head can be used to prepare the convex humeral head. If shoulder resurfacing instruments are not available then reamers designed for surface shoulder replacement. If the biceps remains innervated then tenodesis at this stage will prevent distal migration.

**Preparation of the joint surfaces**

The minimum requirement is that the articular cartilage and subchondral cortical layer is removed from the entire surface of the glenoid, the corresponding area of the humeral head when the arm is positioned in the attitude of intended fusion and from the undersurface of the acromion that will articulate with the humeral head in this position. Although the aim is to preserve as much bone as possible, in practice the majority of the humeral head is decorticated to dispense with the need to accurately predict the final position of arthrodesis at this stage.

In order to preserve bone stock it is helpful to use instruments for decortication that can shave off matching concave and convex surfaces. This can be completed carefully with a high-speed burr. Another alternative is to use reamers designed for surface shoulder replacement. If shoulder resurfacing instruments are not available then acetabular reamers of a similar size to the humeral head can be used to shape the glenoid and undersurface of the acromion simultaneously, whilst curved osteotomes can be used to prepare the convex humeral head.

Occasionally the glenohumeral component of the fusion has excellent bone stock but the contact area with the glenoid is diminished by pushing the humeral head upwards to obtain simultaneous ‘extra articular’ arthrodesis with the undersurface of the acromion. It is acceptable if this occurs to osteotomise the spine of the scapula to allow the acromion, with its attached deltoid, to flap down into contact with the humeral head whilst the head itself makes secure contact with the glenoid. In this position it can be compressed through the plate, though care has to be taken to ensure the plate is long enough to obtain purchase in the spine medial to the osteotomy.

Bone loss can be accommodated by humeral shortening if not severe, or with cancellous grafting if the bone quality is impaired, as might be the case after removal of a prosthesis. In cases of tumour resection or failed shoulder replacement with bone loss, consideration should have been given to using a vascularised bone graft.

**Position of arthrodesis**

At the end of the day a position that permits maximum function. Although there have been many opinions expressed as to the ideal position, any increase in one particular angle results in a diminution of range in the opposite direction and the ideal position may vary from patient to patient, as it depends on desired functions. However, once the arthrodesis has been performed the range of available movement will depend entirely on scapulothoracic movement, so the fusion must be positioned to take full advantage of this. A working party reported on the ideal position for arthrodesis in 1942 and there was immediate controversy not only on the recommendations made, but also on the methods of measurement used (abduction angle was measured between the lateral border of the scapula and the humerus, with a recommended angle of 45–50°, whereas many refer to the angle between the humerus and the vertical axis when the patient is standing).

A surprising range of movement is possible after fusion, accompanied by inevitable scapular winging at the end range, though in this case the winging is brought about by muscle activity pulling the scapula away from the chest wall to increase range and not usually by muscle weakness. It is pointless, therefore, to fuse the shoulder with the arm by the side. Abduction would still be possible by rotating the scapula: a greater range is possible if the arm is fused in a position of abduction to begin with. Every 10° of increased fusion angle results in a further 10° of available abduction range. However the position of abduction must leave sufficient scapulothoracic range for the arm to be returned to the side. Fixed abduction is painful, as the scapulothoracic articulation is strained and fatigues, and should be avoided.

Likewise, care has to be taken in choosing a position of internal/external rotation. Scapular protraction and retraction allows apparent internal and external rotation of the arm after arthrodesis. If the fusion is established with the arm in too much internal rotation, elbow flexion brings the forearm into contact with the abdomen and retraction of the scapula brings about limited apparent external rotation. On the other hand, if fused in excessive external rotation the hand is in a useful position for work but even with full scapular protraction the hand cannot be brought to the mouth.

Although the final position can be discussed with the patient it is useful to offer advice on what has been tried and trusted in the past. The authors preference is the ‘30/30/30’ position, that is with the humerus in 30° of abduction in the coronal plane, 30° of flexion in the sagittal
plane and 30° of internal rotation, allowing the hand to reach the pocket and the mouth.

**Fixation**

The principle of fixation, as indicated above, is to compress the surfaces that are to be fused. Before the plate arthrodesis methods popularised by the AO group, screw arthrodesis was favoured. This was supported by external bracing until bony union. The duration and extent of external bracing required was reduced by neutralising external forces across the lag screw fixation using dynamic compression plates.

Assuming a single plate is to be used, this should be sufficiently strong for the forces it will encounter, and small fragment plates are simply not up to the task. Large fragment plates are needed and although reconstruction plates are more easily contoured, for many patients the additional strength of a standard plate is required. Careful contouring is needed so that, when the arm is held in the intended position of fusion, the plate sits perfectly along the scapular spine, acromion then curves smoothly onto the humerus. Since the humerus is in a position of flexion the plate usually has to be twisted in order that it can lie on the anterolateral surface. A small channel can be cut into the lateral edge of the acromion so that the plate can be sunk into the edge as it crosses this bony prominence. This reduces the significant prominence of the plate that can result in this location, particularly in thin individuals and those with deltoid wasting. A small amount of overcontouring can be performed such that the last turn of the lag screw compresses the plate onto bone. More should be avoided so as not to influence the position of arthrodesis by reducing the intended abduction angle.

Once the plate is accurately bent the fixation can be achieved. The arm is held in the intended position and humeroglenoid fixation is achieved using a large, partly threaded cancellous screw inserted through an appropriate hole in the plate if possible. Further lag screws can then be inserted through the acromion into the humeral head and neutralisation screws in the glenoid neck, scapular spine and humeral shaft.

**Postoperative management**

A period of brace support is conventional after shoulder arthrodesis. Six weeks allows significant progress towards union and load sharing with the unifying arthrodesis. Long-term function depends on rehabilitation of the scapulohumeral joint, however, so scapulohumeral mobility and strength can be worked upon as soon as postoperative pain settles. Physiotherapists can also help preserve joint mobility in the elbow and hand, particularly if the neurological status before surgery demands. During the period of bracing it is permissible for the brace to be removed and the arm supported manually to allow for bathing.

**Alternative methods**

Although screw fixation was largely abandoned after the introduction of plate techniques, there has been a resurgence of interest, as this method is more amenable to minimally invasive and arthroscopic techniques. The non-union rate has been reported to be higher after screw techniques, with inferior mechanical strength associated with screw fixation. Recent mechanical studies have suggested that alternative patterns of screw insertion, with up to six lag screws, may give mechanical conditions at the shoulder joint similar to plate arthrodesis, raising the possibility that similar union rates might be achievable.

Decortication of the surfaces is still required, however, and although this can be carried out through a limited incision, arthroscopy allows complete decortication using a power shaver through only two or three portals. Although arthroscopic arthrodesis has been described there are only few, small series available with limited follow up, so the place of this technique has yet to be established.

**Results**

If complications do not ensue, shoulder arthrodesis leads to high levels of shoulder function and improved function. It has to be remembered, however, that the procedure is usually being carried out because of severe neurological or destructive pathology, so routine outcome measures such as the constant score should be interpreted in terms of the improvement that occurs after surgery. The absolute score achieved will be low compared to what is observed after virtually any other shoulder procedure. The constant score includes 40 points for range of movement along with 25 more points for power measured in a position of the arm that is usually impossible to achieve after shoulder arthrodesis.

After appropriate scapulothoracic mobilisations and training a very useful range of ‘shoulder’ movement can be achieved. Clearly the range depends on the position of fusion and therefore the range reported in the literature is wide. As a guide, most patients will achieve flexion and abduction up to the horizontal level, with sufficient ‘rotation’ (scapulothoracic protraction and retraction) to each the front pocket and, to a lesser extent, the back pocket. Functions that do not involve overhead positioning or significant rotation are usually well within the capabilities of the patient, including tasks that require the lifting of heavy weights.

**Complications**

The major complications occurring after attempted shoulder arthrodesis are non-union, fracture and persisting pain. Furthermore the procedure can be complicated by infection, poor positioning and rarer complications such as pneumothorax. In the largest series reported to date, 35 patients (25 of 71) required reoperation for complications.

Non-union rates vary, but Coefield and Briggs described three non-unions in 71 arthrodeses. A recent study including both screw and plate arthrodeses reported a rate of three non-unions in 30 cases, though the authors had carried out arthrodesis for challenging indications, such as infection and for reconstruction after removal of a shoulder prosthesis. In general non-union can be successfully managed by grafting and compression plating, replacing the original fixation if necessary.
Humeral shaft fracture occurs much more frequently after shoulder arthrodesis than, for example, after plating of proximal humeral fractures (Figure 4). Without the mobility of the glenohumeral articulation, forces transmitted from the arm traverse the vulnerable junction at the tip of the plate. After disuse the humeral shaft is weakened by mineral loss and fracture at this site is reported in approximately 10%; prophylactic grafting has even been recommended. 14 Non-operative management with humeral bracing is satisfactory for the majority of cases, though if the fracture occurs after union of the arthrodesis then consideration can be given to removing the arthrodesis plate and treating the new fracture by internal fixation.

Persisting pain is not at all unusual after arthrodesis; in cases of arthrodesis for end stage instability persistence of the sensation of dislocation can even continue after fusion occurs. Overall, substantial relief of pain is reported, though unfortunately any neurogenic pain associated with brachial plexus injury is unlikely to be improved.

Summary and Conclusion

Shoulder arthrodesis is primarily indicated in cases of brachial plexus trauma where scapular control remains intact, but there is irrecoverable loss of rotator cuff and deltoid function. The flail arm regains an active range of motion derived from the scapulothoracic joint that restores useful shoulder function and restores the ability to exert some control over hand positioning. A fusion position of approximately 30° each of abduction, forward flexion and internal rotation is preferred. Substantial scapulothoracic conditioning is required during rehabilitation, and it is not uncommon for some discomfort to persist. For most indications other than paralysis arthrodesis should be avoided if alternative methods, such as joint replacement, are feasible. However, it remains a very valuable technique for difficult and revision reconstructive problems about the shoulder.

References